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Manganese-56 Coincidence-Counting Facility Precisely Measures Neutron-Source Strength

The problem:

To develop an absolute counting facility for precise measurement of neutron-source strength. Customary counting methods, using the manganese-bath technique, lack the required precision. The Mn^{56}-decay scheme, a beta-counting technique, requires an extremely large liquid sample. Beta-scintillation counting, through direct contact of the solution with plastic scintillators, is complicated by light collection, surface area, etc.

The solution:

A Mn^{56} counting facility capable of precise measurements (within 1%) of neutron-source strengths by the manganese-bath technique. Two-liter liquid samples of $Mn^{56}SO_4$ are counted in a gamma-gamma coincidence arrangement by the two-stage absolute counting facility. The system is calibrated on an absolute scale by another unit that counts aliquots of strongly activated samples mixed with liquid scintillator in a $4\pi\beta/\gamma$ (beta-gamma) coincidence mode. The combined system yields an absolute measurement. This facility combines nuclear instrumentation with coincidence-counting techniques to handle a wide range of radioisotope-counting requirements.

How it's done:

A two-stage measurement provides the precision required in measurement of neutron-source strength. The gamma-gamma coincidence setup is designed for relatively low background, optimum efficiency, and long-term reproducibility; the beta-gamma coincidence unit has high counting-rate capabilities, maximum efficiency, and appropriate precision. Most of the electronic circuitry is common to both units.

In the γ-γ system, two 4- by 5-in. sodium iodide crystals are mounted so that 2 liters of $Mn^{56}SO_4$ solution can surround the detectors in an annulus. The solution can be poured in through a tube that emerges from the lead shielding. Phototube signals are amplified and shaped in two doubly differentiating amplifiers. The pulses are timed from the zero crossing, selected as to energy by two single-channel pulse-height analyzers, and finally placed in coincidence. Manganese-56 gammas have energies of 0.845 MeV, in coincidence with 1.8 or 2.1 MeV. A delay, mixing, splitting, and repeating artifice permits counting of the 0.845-MeV radiation from either crystal, while still obtaining valid coincidences with the lines of higher energy from the opposite detector.

The β-γ system is based on the fact that β-emission of Mn^{56} is 100% in coincidence with γ-emission, and that most beta particles have high energies. Aliquots of activated Mn solution are added to a liquid scintillator, having a β-detection efficiency of 98% and a background level of 1.3 Hz, that can handle count rates up to 10^4 Hz with great accuracy. The accompanying gamma channel features a 3-in. NaI (Tl) scintillator.

Operation of the beta detectors at room temperature with low noise rates is achieved by establishment of a photoelectron-coincidence requirement between two photomultiplier tubes with the same scintillation event. The pulses are fed directly from high-gain phototubes into a pair of tunnel-diode discriminators biased to accept pulses due to a single photoelectron; they are then fed into a coincidence analyzer and subsequently into time analysis with gamma channel.

(continued overleaf)

Notes:

1. Additional information available includes all details of procedures, method of intercalibration, data-accumulation and processing methods of sample preparation, and results of testing and evaluation of the two systems.
2. This information may interest the drug industry and the medical community.
3. Inquiries concerning this information may be directed to:

   Office of Industrial Cooperation
   Argonne National Laboratory
   9700 South Cass Avenue
   Argonne, Illinois 60439
   Reference: B69-10621

Source: 1. A. DeVolpi and K.G.A. Porges
Reactor Physics Division
2. R. N. Larsen
Electronics Division
(ARG-90261)

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Mr. George H. Lee, Chief
Chicago Patent Group
U.S. Atomic Energy Commission
Chicago Operations Office
9800 Cass Avenue
Argonne, Illinois 60439